In-flight Integrated Mission Management System (I-LIMMS)

Final Technical Report

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FINAL REPORT

1. Objective

The goal of this Phase I SBIR effort was to determine the feasibility and preliminary design of I-LIMMS, an In-flight Lidar Integrated Mission Management System for the processing and visualization of lidar and in-situ data aboard an aircraft. This proposed effort included tasks for defining all interfaces, defining the necessary hardware requirements, defining and/or selecting the existing software to carry out the task, and developing proto-type architecture for the future I-LIMMS.

Ultimately, it is hoped that, upon completion of Phase II and Phase III studies, that I-LIMMS will include the following features:

- User interface that enables non-instrument scientists conducting multi-purpose research to operate the full suite of instruments including the lidar
- 4-d visualization and interactive real-time mission management options/scenarios as well as post-mission playback
- On-screen guidance for in-flight mission operations and decisions such as the positioning of aircraft and instrumentation to meet stated mission objectives (i.e., selecting the level to fly to intercept wind shear, aerosol and cloud features).
- Integrated display of on-board radar data and SatCom available satellite imagery and numerical model output data
- Background monitor of the health and safety of the on-board instrumentation including the DWL through an alert system for hardware as well as providing diagnostic instructions to allow non-specialists to rectify problems and abnormalities.

2. Approach

The detailed approach taken during this Phase I research effort is provided below in the summary of work completed for the various tasks spelled out in the Phase I proposal.

3. Work Completed

Presented below is a detailed summary of the work completed for this SBIR Phase I effort on a task by task basis.

3.1 Select and evaluate Commercial Off The Shelf (COTS) 3-D data display software for both real-time and post-flight visualization and analysis of data

The goal of this task was to identify the software package(s) or combination of packages that have the following features:

- Extensible to any geo-referenced data
- Easy to use on-board an aircraft
- Handle data of many types/formats from multiple platforms including lidar, in-situ aircraft, radar, satellite and models,
- Provide a near continuous display of the atmospheric environment at, below, and above flight level.

SWA spent considerable time evaluating and testing existing 3-D visualization packages with these requirements in mind. These COTS software packages included but were not limited to Unidata's Integrated Data Viewer (IDV), University of Wisconsin's Vis5D, RSI's ENVI/IDL, Skyline's Terra Explorer and National Instrument's LabVIEW. This evaluation has been done through personal communication with vendors, personal and on-line demonstrations of the software, attending seminars and workshops, and in-depth evaluations of several of the packages.

After much research, testing and evaluation, SWA recommends LabVIEW and ENVI/IDL as the best candidates for the work to be done in Phase II and Phase III.

3.2 Identify all interface requirements between existing in-situ data (aerosol probes, for example), model data, SatCom products and remote (lidar, radar) airborne sensors on the CIRPAS Twin Otter

Through discussions and correspondence with CIRPAS personnel (Haflidi Jonsson), Simpson Weather Associates (SWA) has identified the most up-to-date listing of facility/aircraft measurements and research measurements that will be possible aboard the Twin Otter aircraft. In addition to wind lidar measurements, the research measurements will include, among others, cloud radar, condensation nucleus counters (CNC), Tandem Differential Mobility Analyzer (TDMA) and stabilized radiometers. SWA has also identified both the existing visualization software that will be supplemented by I-LIMMS and the software and hardware interfaces to incorporate the existing data stream into I-LIMMS.

In further discussions with CIRPAS, SWA suggested that the current data system in place on the Twin Otter and the I-LIMMS be considered as independent options for a mission scientist. Since the I-LIMMS is lidar centric, it is not critical, nor desirable, to replace the current data system which is the product of many years of experience. Thus, SWA's I-LIMMS would be used only when there is a lidar onboard. When I-LIMMS is selected for data display, it would obtain feeds from the current data system for display of general information in the multiple displays of the I-LIMMS GUI. CIRPAS personnel (Jonsson and Roy) agreed that this would be the most robust way to proceed.

At some point, it may be desirable to merge the two systems, but in the near term separate development and utilization is desirable. In general, this approach is also less risky.

3.3 Define a testbed for prototyping I-LIMMS and data benchmarking

In response to this task, SWA developed a data testbed, the general architecture and preliminary design for the onboard integrated processing and visualization of DWL (already existing), in-situ, satellite, model and radar measurements (I-LIMMS). The I-LIMMS testbed will provide an environment for individual component and integrated testing of the I-LIMMS. The testbed can subsequently be used for evaluation of Phase II experiments and consequent modifications of the code.

The preliminary design of I-LIMMS, including main screen and model functionality, is detailed below in Figure 1 which depicts a mock-up of the main I-LIMMS screen. The design of the screen divides the monitor screen into three functionality panels; Vertical Left, Horizontal Top and Main Visual.

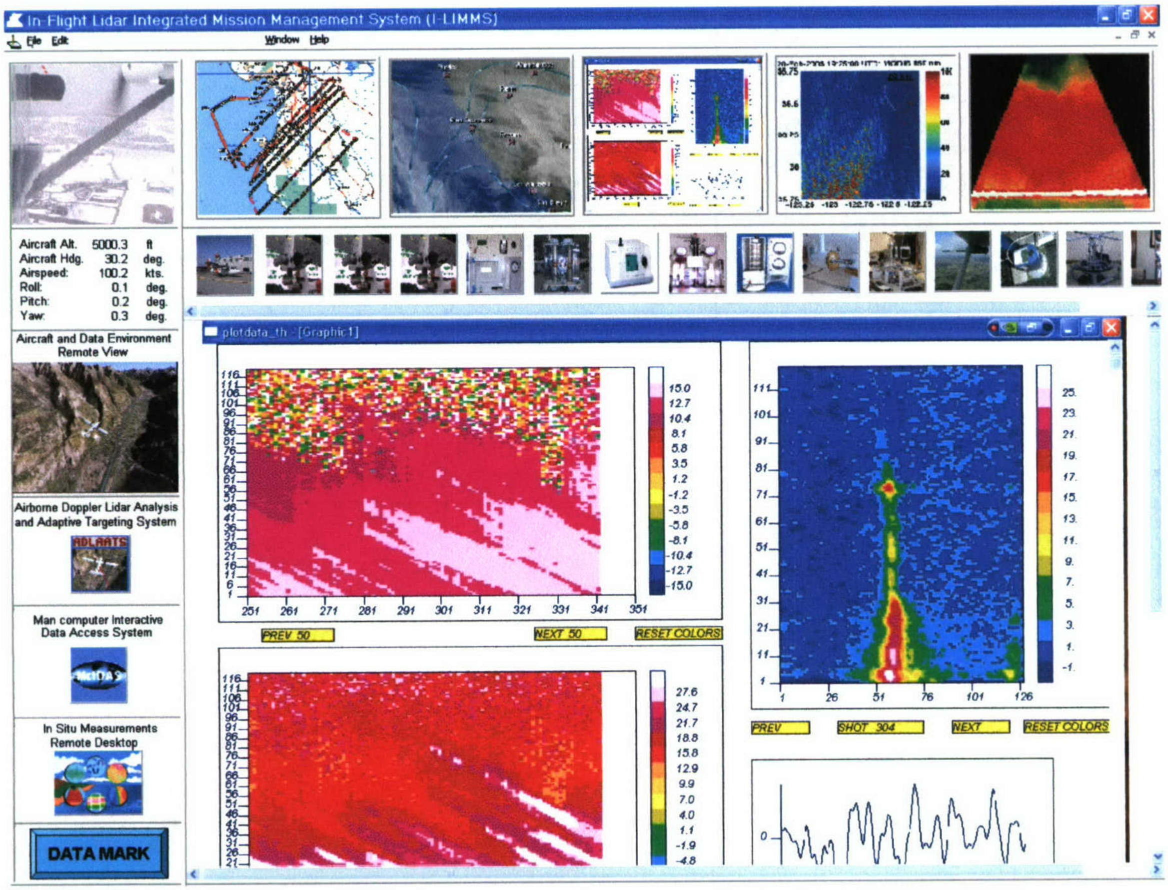

Figure 1: The main screen for the In Flight Lidar Integrated Mission Management System (I-LIMMS). This figure is a SWA proprietary document.

The Vertical Left panel is intended for aircraft navigation information, aircraft video and independent model operations. Currently the independent models are identified as the Airborne Doppler Lidar Analysis and Adaptive Targeting System (ADLAATS), Aircraft and Data Environment Remote View (ADERV) and Man computer Interactive Data Access System (McIDAS). There is a remote desktop option to interact with the computer that controls the In Situ instruments. A Data Mark button that allows the user the mark and document significant events in the data is also included.

The Horizontal Top panel contains five independent visual displays that allow the user to view current measured data such as Doppler Wind Lidar (DWL) products, in situ measurements as well as incoming observations such as satellite imagery and radar. Graphics depicting aircraft specifics are also included. Below the five screens is a slider bar containing a menu of icons for the user to choose which visual product to display. Each instrument icon can be dragged and dropped into any of the five displays to invoke a visual tool and data display.

The Main Visual resides below the menu icons and to the right of the left panel. The user can drag and drop any one of the five smaller displays in the Horizontal Top panel into the Main Display for enhanced viewing and graphic customization.

Figure 2 is a flow chart diagram for the In Flight Lidar Integrated Mission Management System. When I-LIMMS is first executed, a pop-up child window will be invoked to display checklist instructions for the user to insure all instruments and communication connections are ready for mission operations.

During the TODWL flight, navigation information, on board in situ data and on board video is provided to I-LIMMS for display and the I-LIMMS database storage. From I-LIMMS, ADLAATS (Shown in figure 3) can be invoked allowing the user to control the DWL, make lidar measurements and process the lidar measurements. All data (RAW, PRD, AUX) produced by ADLAATS is provided to I-LIMMS and the I-LIMMS database storage.

If available, external information such as satellite (McIDAS) and radar imagery is piped to I-LIMMS for visualization and the I-LIMMS database storage. The Aircraft and Data Environment Remote View (ADERV) tool allows the user to view the aircraft remotely, mapping all measured data in the immediate area of the aircraft. See the Horizontal Top Panel discussion above for the explanation of the five small visuals and the Main Visual.

The Mission Manager is an invoked pop-up window that occurs when pre-set conditions are recognized in the data. Suggested mission modifications and instructions are provided to the user when this happens.

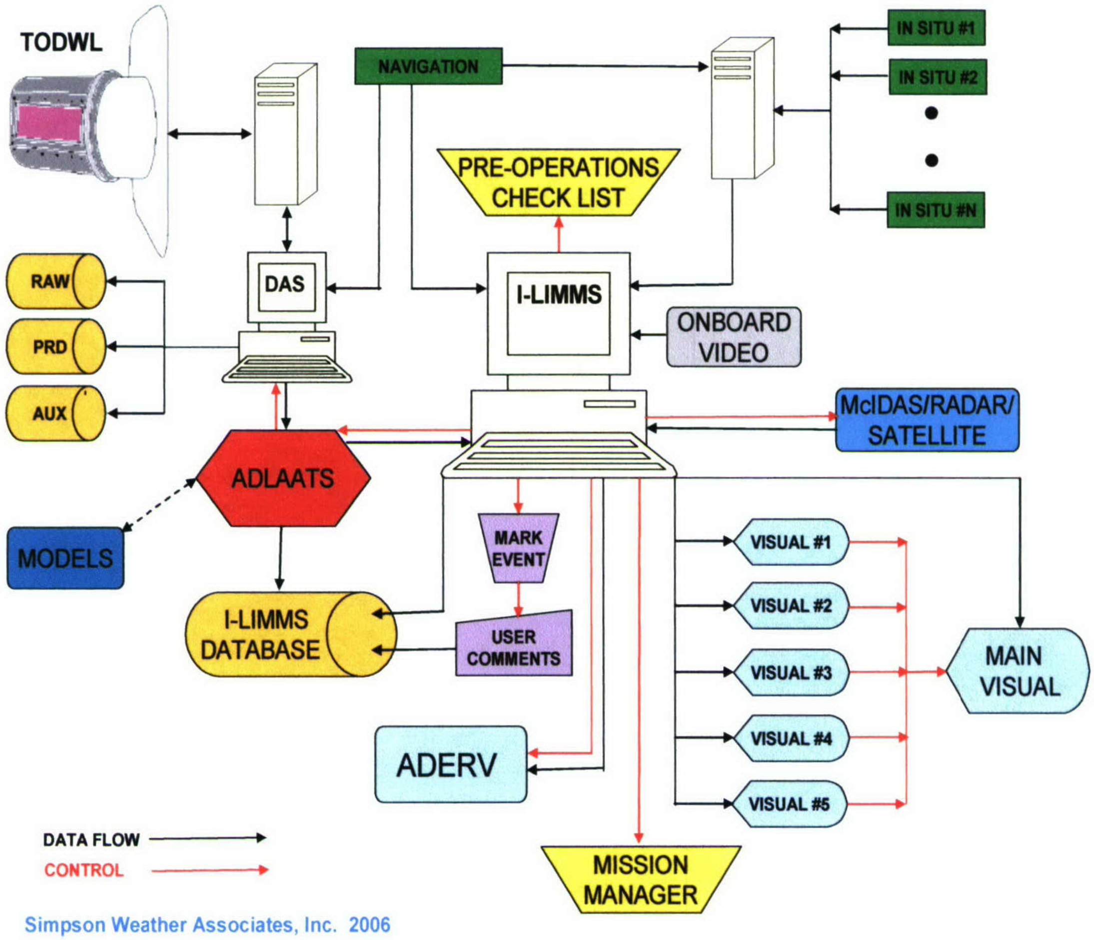

Figure 2: Flowchart of the In Flight Lidar Integrated Mission Management System (I-LIMMS) depicting the data flow and module control. This figure is a SWA proprietary document.

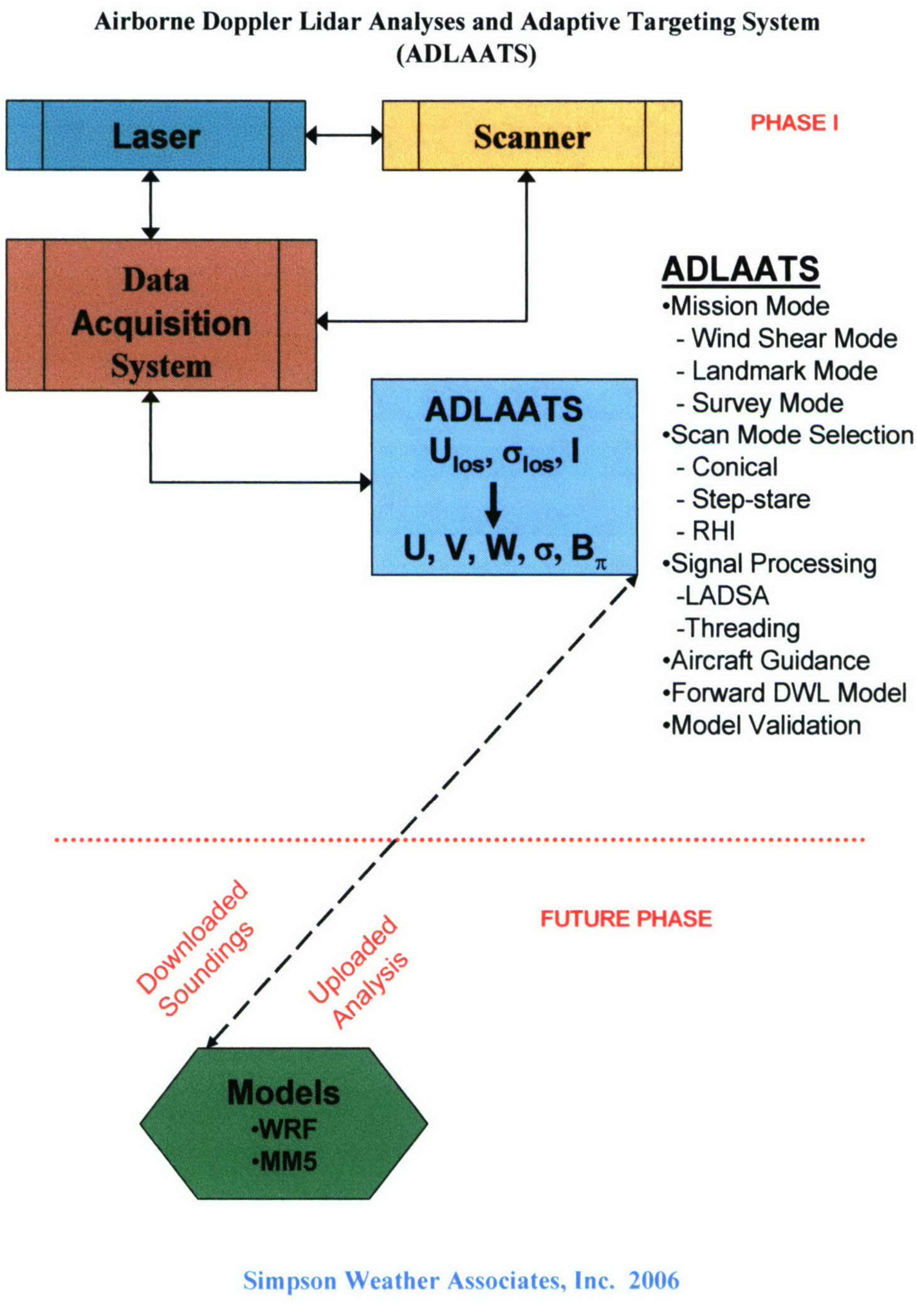

Figure 3: Component diagram of the interfaces between the Airborne Doppler Lidar Analyses and Adaptive Targeting System (ADLAATS), the Doppler wind lidar system, and the information provided by meteorological models or observations. This figure is a SWA proprietary document.

Through a series of tests and using a testbed populated with existing code, we benchmarked the flow of data from the laser, through both the scanning and processing algorithms, and finally to the point where it was ready for visualization and analysis. Special attention was paid to processing time and the timely utility for real-time systems and for visualization. The bandwidth of the up/down link will determine the volume of data that can be accommodated. Computational speeds and file sizes for the lidar data stream are displayed in Table 1. Similar benchmarks will subsequently be completed for other data such as the in-situ measurements and radar/satellite data.

Table 1: Code timing and file size.

OPERATION	EXECUTION TIME	FILE SIZE
Acquire raw data (500MHz)	**5 minutes (15 -20 profiles)**	**20,000kB**
Lidar Attitude Determination and Scanning Algorithm (LADSA)(once per hour)	**90 seconds**	**N/A**
LOS processing (500 shots/LOS/second) w/ threading**	**23 seconds (for 5 minute raw data file)**	**170 kB**
VAD processing (sine fit; multi-Var)**	**35 seconds; 80 seconds (15-20 profiles)**	**140 kB**

* Timing tests were run on a Dell 5100, Pentium 4 CPU w/ 512MB RAM. File size does not reflect any data compression.
** VAD – Velocity Azimuth Display; LOS – Line Of Sight

3.4 Identify the hardware required to implement the mission management system.

One of the proposed tasks was to define or identify hardware options to meet the data, network, software and visualization requirements of I-LIMMS.

Taking into account these requirements and the benchmarked data flow, SWA investigated numerous hardware options from various vendors. After deliberation, it was decided that the Dell Precision 690 Workstation and the Dell Precision M90 laptop offer the best solution. Specifics for these systems are provided in Table 2.

Table 2: Detailed specifics of the two potential systems identified as candidates for I-LIMMS.

	Dell Precision 690 Workstation	**Dell Precision M90 Mobile Workstation**
Processor (Max)	Dual Core Intel Xeon 5160 3.0GHz	2 Duo Processor T7600 2.33GHz Dual
Operating System	Windows XP Professional Windows XP Professional x64 Red Hat Enterprise Linux	Windows XP Professional Windows XP Professional x64

		Windows Vista (capability)
Memory	Quad channel DDR2 at 533 and 667MHz. 512MB to 4GB memory capacity	Dual channel DDR2 at 533 and 667MHz. 512MB to 4GB memory capacity
Graphics	NVIDA Quadro FX 3500 (supports 1-2 dual link connections)	NVIDA Quadro FX 2500M
Hard Drive	Supports up to 5 hard drives and a potential of 2 TB	Up to 120 GB
Display	Various monitor options	17" wide-aspect 16:10
Connectivity	Various options	56K V.92 internal modem; wireless LAN and Broadband options

Both options listed here, with the dual core processing, will provide high performance of multi-threaded application and in a multi-tasking environment that will typify I-LIMMS. Both graphics options are also ideal for graphically demanding applications such as the 3-D modeling and visualization that will be part of I-LIMMS.

3.5 Develop strategy for defining levels of I-LIMMS utility depending upon user's experience.

After considerable discussion with CIRPAS personnel and considering the further development of the ADLAATS software, we have decided not to further pursue this feature. However, in its' place will be a large listing of menu options as part of the visualization component and the mission management component (as described in section 3.6 below).

3.6 Define the major components of a "mode library" populated by a number of measurements modes (i.e., wind shear mode or landmark mode) that are visualized for the flight manager and help direct the in-flight mission.

The "mode library" that will aide the in-flight manger in achieving mission objectives will be provided through the ADLAATS software. As shown in Figure 3 and discussed previously, ADLAATS can be invoked allowing the user to control the DWL, make lidar measurements and process the lidar measurements.

The options provided by ADLAATS will include but may not be limited to the following:

- Mission Mode:
  - Wind shear mode
  - Landmark mode
  - Survey mode

- Lidar scanning strategies
  - Conical
  - Step-stare
  - RHI
- Signal Processing
  - LADSA
  - Threading
- Aircraft Guidance
- Model Validation

3.7 Phase I transition option

Although not officially awarded, SWA personnel have already begun the process of modifying and converting existing code so that it will operate in the planned .net environment of I-LIMMS.

4. Results and Conclusions

We have met all the objectives of the proposed Phase I effort. Assessments of software needs have led to a decision to blend COTS with customized code. The processing of the lidar data will be accomplished with existing code (research code converted to operational code) while the GUI and 3-D data display will be done with a combination of COTS and some "glueware".

The bench testing of the processing code has led to a clear specification of the computing platform requirements which are easily met with readily available hardware.

As is the case in this type of unique software development, the challenges lie primarily in the interfaces between systems. SWA has a long experience in working these interfaces and anticipates being able to meet the challenges.

Based upon the results of this feasibility study, SWA concludes that the I-LIMMS, while representing unique and original ideas in the use of DWLK data in flight, is both doable technically and cost wise during a Phase II effort.

5. Recommendations

SWA recommends that ONR proceed with a Phase II contract for the development of I-LIMMS. SWA further recommends that the Phase II contract include sufficient resources to fully test I-LIMMS during Twin Otter flights. It is expected that a "non-instrument" scientist would participate as a beta tester for the utility of the user interface. This tire kicking should take place well before the schedule delivery time for the Phase II product.

SWA also recommends that CIRPAS be enabled to provide direct support to the integration of the current Twin Otter data system with the I-LIMMS. This will insure that overlap is minimized and that one of the end users (CIRPAS) has both a working knowledge of I-LIMMS and the opportunity to have input to the end product design and function.

6. Summary for Follow on Phase II Research and Development and Beyond

Following upon this Phase I effort, we would like to do the following during a Phase II study

- Acquire freeware or COTS version of the 3-D visualization software
- Acquire the appropriate hardware that needs to be installed on the CIRPAS Twin Otter
- Fully populate the a .net version of the I-LIMMS testbed with all required functions and perform end-to-end evaluations of the code and visualization packages in the laboratory and later within the aircraft.
- Resolve any timeliness issues identified in Phase I with the goal of processing, analyzing, transmitting and visualizing information every 10 minutes or less.
- Design and conduct flight experiments on the CIRPAS Twin Otter to demonstrate the functionality of I-LIMMS and to investigate the potential impact of the wind and aerosol data to the Navy
- Refine and detail the notional commercialization plan for marketing I-LIMMS post Phase II.

It is hoped that I-LIMMS will eventually prove to be very beneficial to planned and future measurement platforms including lidar measurements. Since the current DWL technology requires significant platform resources, agencies such as NASA and the DoD are investing in DWL technology that could be accommodated on UAVs (Unmanned Aerospace Vehicles). There are obvious advantages to such aircraft and their measurement of winds and aerosols for military, homeland security and atmospheric research. SWA is interested in being involved with the application of such a DWL-centric mission management and visualization system for use by the military, operational scientists and atmospheric researchers conducting airborne missions and studies. Further downstream, SWA is very interested in adapting the proposed I-LIMMS to UAVs.

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14. ABSTRACT
During the Phase I effort, Simpson Weather Associates (SWA) developed a data testbed, the general architecture and preliminary design for an onboard integrated processing and visualization of Doppler wind lidar, in-situ, satellite, model and radar measurements. This system is known as I-LIMMS (In-flight Lidar Integrated Mission Management System) and will supplement existing software and processing already in place onboard the CIRPAS Twin Otter.

The architecture and options for a lidar observation "mode library" to be used in mission management have also been identified and incorporated into the software design. This software will provide options for mission mode, lidar scanning, signal processing and model validation.

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